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ABSTRACT

A study investigated the effectiveness of an intervention for improving adolescent writing and speaking using mathematical language. The targeted population consists of high school students in a growing, middle- and upper-middle-class, suburban community located west of Chicago, Illinois. The problems of writing and speaking using mathematical language have been documented by data collected from teacher observations, student interviews, and teacher-made assessments. Analysis of probable cause data reveals that students lack the basic understanding of math vocabulary, lack confidence in their math abilities, and lack the knowledge of math writing skills. Reviews of curricular content and previous instructional methods reveal an over-emphasis on basic skills and computation with minimal attention to writing and speaking using mathematical language. Solution strategies suggested by knowledgeable others, combined with an analysis of the problem setting has resulted in a selection of one major intervention--an increase of instructional emphasis on writing and speaking using mathematical language through the use of journal writing, cooperative learning, and portfolio assessment. Results indicated that: (1) students' attitudes toward writing and mathematics improved; (2) students' understanding of mathematics improved; and (3) students showed an increase in their ability to talk mathematically. Contains 34 references and 7 tables of data. Appendixes present survey instruments, interview questions, sample journal questions, a sample social skills lesson plan, sample test questions, and group self-evaluations. (Author/RS)

IMPROVING WRITING AND SPEAKING SKILLS USING MATHEMATICAL LANGUAGE

by

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Submitted in partial fulfillment of the requirements for the degree of Master's of Arts in Teaching and Leadership

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To: Victoria

You started this project with me and I hope you will always love to learn.

ABSTRACT

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DATE: May 1995

TITLE: Improving Writing and Speaking Using Mathematical Language

ABSTRACT: This report describes an intervention for improving adolescent writing and speaking using mathematical language. The targeted population consists of high school students in a growing, middle and upper-middle class, suburban community, located west of Chicago. The problems of writing and speaking using mathematical language have been documented by data collected from teacher observations, student interviews, and teacher-made assessments.

Analysis of probable cause data reveals that students lack the basic understanding of math vocabulary, lack confidence in their math abilities, and lack the knowledge of math writing skills. Reviews of curricula content and previous instructional methods reveal an over-emphasis on basic skills and computation with minimal attention to writing and speaking using mathematical language.

Solution strategies suggested by knowledgeable others, combined with an analysis of the problem setting has resulted in a selection of one major intervention; an increase of instructional emphasis on writing and speaking using mathematical language.

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Chapter 1

PROBLEM STATEMENT AND COMMUNITY BACKGROUND

General Statement of Problem

The targeted freshman and sophomores at Addison Trail High School and St. Charles High School lack the ability to write and speak using the language of mathematics. This is evidenced by teacher observation, teacher-made tests, and student interviews.

Immediate Problem Context

Addison Trail High School serves grades nine through twelve with a total population of 1,670 students and a professional staff of 130 who are administered by a principal, three assistant principals, and 11 department heads. The average class consists of 21.6 students. Teachers at Addison Trail have an average teaching experience of 19.5 years with 85.8 percent holding a master's degree or master's plus additional education hours. While racially and ethnically mixed the largest population is Caucasian at 79.5 percent, followed by a Hispanic population of 13.6 percent with the remainder being African-American or Asian. In accordance with this school's diverse population there exists a 5.6 percent of limited-English proficient students who are eligible for bilingual education. Addison Trail also has 5.7 percent group of students from low-income families (School Report Card, 1994).

The mathematics department consists of 13 teachers: 5 women and 8 men who teach a total of 60 mathematics classes. Addison also employs a bilingual mathematics teacher who instructs two sections using the Spanish language. Students entering the mathematics curriculum at Addison Trail High School will take one of several different paths to meet the two year state requirement. The average student begins with Algebra, moves on to Geometry, Advanced Algebra, and finally Analysis with Trigonometry. The more advanced student will enter Honors Geometry or regular Geometry, then continue with Advanced Algebra Honors, Analysis with Trigonometry Honors, and Calculus. Finally, the lower level students enter Essentials of Algebra I, continue with Essentials of Algebra II, Essentials of Geometry, and Intermediate Algebra. General Math and Consumer Math classes are available for those students whose abilities do not meet the low level track.

Computer labs and calculators are available from the department to help students learn. The school has both MAC and DOS labs with a variety of mathematics programs including Geometry Sketchpad and Lotus 1-2-3. Calculators are required in several classes, therefore the department owns five classroom sets which includes scientific calculators and TI-81 and TI-82 graphing calculators.

Addison Trail has an eight period school day where classes are 50 minutes long. A mathematics teacher is always available at the mathematics resource center to provide needed assistance. Additional help is usually available both before and after school by appointment. All students receive quarter grades; and progress reports mailed to the parents every four and a half weeks.

St. Charles High School has a population of 2,800 students served by a professional staff of 185. The high school is the single public facility serving students in grades nine through twelve. The school's population is approximately 95 percent white and approximately five percent either Black, Hispanic, Asian, or Native American. The majority of families fall in the middle to upper-middle income range. There is approximately one percent of students who are eligible for bilingual education. The dropout rate is two and one-half percent (School Report Card, 1994).

The administrative team consists of one principal, two assistant principals, three full-time deans, two part-time deans, one athletic director, and eight supervisors of the subject area departments.

The staff of the mathematics department consists of 21 fully certified teachers; average years of teaching experience is 13. Fifty-four percent of the teachers have a master's degree, with 12 percent having a master's degree plus 30 hours, and 35 percent with a master's degree plus more than 30 hours. The average age of the mathematics department is 38 years old. The ten women and eleven men are responsible for teaching levels of mathematics ranging from basic mathematics to college level calculus (School Report Card, 1994).

The original facility is approximately 20 years old. Three years later an addition was built to complete the high school except for the school's field house which was built approximately 13 years ago. During the present school year a referendum has been passed to construct a new facility to accommodate 900 students. The average class size for St. Charles High School is 21, however, growth has been steadily increasing due to construction in this area. There are several mathematics classrooms equipped with screens, overhead projectors,

and blackboards to facilitate the teaching of mathematics. There are also five classrooms equipped with computers for each student and are available to all teachers on a daily sign-out basis. The mathematics department is equipped with several classroom sets of graphing calculators. Classes are 50 minutes long with six minutes between classes. Every student is required to pass two years of mathematics; placement is based on test scores and teacher recommendation from eighth grade and most ninth graders begin with the Algebra I course. The majority of classes have different levels of ability ranging from an average level to a honors level.

Currently the entire high school has identified the following four areas for improvement: communicate effectively, think critically, think creatively, and exhibit student responsibility. In accordance with school goals, the mathematics department strives to develop independent, creative and critical thinkers.

The Surrounding Communities

Addison, the fourth largest industrial town in the state of Illinois is located twenty miles west of Chicago, and has 1,200 acres of industrial park. There are 569 industrial units containing both large and small facilities with major national names. Addison, a middle class community with the median age of 30 and the median family income of $39,553, has a population of 32,058 according to the 1990 census. According to the 1991 Addison Community Directory the ethnic make-up of the community is 78.97 percent white, 13.37 percent Spanish, and the remainder consists of 0.12 percent Native-American, 5.86 percent Asian-Pacific Islander, and 1.61 percent black.

Addison's students enroll in two public school districts: District #4 which is an elementary district with seven grade schools and one junior high school and High School District #88 which contains Addison Trail. In addition to the public schools there is also a catholic high school to serve the community. District #88 contains two high schools: Willowbrook High School which is located in neighboring Villa Park and Addison Trail High School located in Addison. The community of Addison is heavily involved in the school systems and places a high value on education. During the 1993-1994 school year there was a motion to combine both the grade school and high school districts into a unit district. While this was defeated by the state superintendent it is still a consideration among some of the local population. Currently District #88 policies are determined by an elected school board that makes decisions on facilities, staff, educational programs, and financial matters.

West of Addison, St. Charles, Illinois is located approximately 40 miles west of Chicago. The 1990 census lists the population at 27,500 and the township population at 33,112. Community Unit School District #303 has a student population of 9,000; projected enrollment for September of 2000 is 10,587. There are presently nine elementary schools, two middle schools, and St. Charles High School. Due to the passage of the 1993 referendum, a new middle school will be build on the west side of town. Likewise, a new "900 Student Center" will be built on the existing high school campus, and all other existing buildings will receive additions which are projected to be completed in 1996.

The district student population is composed of approximately 96 percent White, 1 percent Black, 2 percent Asian/Pacific Islanders. One percent of the districts' student population has limited English proficiency.

Regional and National Context of Problem

Nationally, communication skills of secondary students in mathematics are very low. A study conducted by the International Association for the Evaluation of Education Achievement (1988) compares mathematics scores among students from the United States and students from nineteen other countries. This research used mathematics problems to test students and looked at the methods of teaching and learning in secondary schools. The study included other surveys such as: attitudes towards mathematics, curriculum differentiation and intensity, homework, class size, yearly hours of mathematics instruction, teacher background and attitudes, role of the mathematics textbook, and the extent of calculator use. In all tests, students from the United States scored average to below average. The International Association for the Evaluation of Education Achievement (1988) describes the problem:

> In school mathematics the United States is an underachieving nation, and our curriculum is helping to create a nation of underachievers. We are not what we ought to be; we are not even close to what we can be. It is time for change -- a time to renew school mathematics in the United States (p. 5).

Our country has changed from an industrial to an informational society, thus what our students learn and how they learn it must change to keep pace. Students need to learn to value mathematics, to reason, to communicate mathematically, and to become confident in their power to use mathematics coherently to make sense of problematic situations in the world around them (Romberg, 1993).

The education system as it was served an industrial society (NCTM, 1989). Workers then needed strong backs, clever hands, and 'shopkeeper' arithmetic skills. "Information is the new capital and the new material, and communication is the new means of production" (NCTM, 1989, p. 3). Today workers need education to understand the complexities and technologies of communication to ask questions, to adapt new information, and to work cooperatively in teams. The skills students need now and in the future must represent these needs. The ability to read, write, listen, think creatively, and communicate about problems will develop and deepen students' understanding of mathematics (NCTM, 1989).

As rote computation becomes less important, the skills and understanding required to use calculators and computers become more important. Technology is more available and students are required to come to class with calculators and have access to computers. This has eliminated the need for students to repeat learning rote skills year after year. "Instruction has emphasized computational facility at the expense of a broad, integrated view of mathematics and has reflected neither the vitality of the subject nor the characteristics of the students" (NCTM, 1989 p. 65).

Writing can help students in many different ways. By learning and writing about related topics, by writing about problems which puzzle them, by writing about their fears and feelings, students begin to see mathematics in more human terms (Schmidt, 1985). If students can write clearly about mathematical ideas, then it is clear that they understand those ideas. Students who write in mathematics must do considerable thinking and organizing of their thoughts to crystallize in their minds what they have studied (Johnson, 1983).

"All students need to learn more, and often different, mathematics and that instruction in mathematics must be significantly revised." (NCTM, 1989, p.1) There is no question that the current school mathematics curriculum is out-of-date. The majority of American students do not have an opportunity to become empowered mathematically even though our culture demands mathematical literacy of its citizens (Romberg, 1993). Speaking and writing about mathematics problems can contribute significantly to understanding (LeGere, 1991).

Chapter 2

PROBLEM EVIDENCE AND PROBABLE CAUSE

Problem Evidence

Writing in the mathematics classroom has been a key topic for discussion at many conventions in the United States, and is slowly moving towards implementation. Continued support and encouragement for students to express their mathematical thoughts through writing and speaking reinforces the connection between mathematics and our society (NCTM, 1989). "Writing, especially original composition involves active manipulation of knowledge, many of the thought processes related to creative thinking, and the development of problem solving strategies" (Davison & Pearce, 1988, p.493). Davison and Pearce (1988) document the lack of opportunities for writing activities in the mathematics classroom. Data was collected from 31 junior high schools to study the amount, kinds and uses of writing in mathematics. The researcher chose five commonly used textbooks used in seventh and eight grade classrooms. These textbooks included: Addison-Wesley (Addison-Wesley Mathematics, 1987), Heath (Heath Mathematics, 1987), Houghton Mifflin (Houghton Mifflin, 1987), and Scott Foresman (Invitation to Mathematics 1985). A classification system was developed by the researcher to determine the types of writing activities in a mathematics textbook. The classification system was made up of three categories,

including: response to a question, problem formulation, and project/report. In the first category, response to a question, the students were asked to respond to a specific question using one or two sentences. The second category, problem formulation, students were asked to generate a written problem using specific data or using problem previously encountered. The last category, project/report, consisted of writing activities that required students to develop a method for solving real life problem situations and to include a written summary in response to the mathematical situation or to report on the findings. A summary of the types of writing activities found in the textbooks and the number of instances each type occurred is presented in Table 1.

Table 1

Number of Instances of All Writing Activities in the Student Texts

	GRADE 7				**GRADE 8**			
	Type				**Type**			
Series	1	2	3	***Total***	1	2	3	***Total***
A	16	0	2	18	14	2	0	16
B	7	20	0	27	5	18	0	23
C	39	8	1	48	57	16	1	74
D	59	5	0	64	47	5	1	53
E	5	5	0	10	4	10	0	14

Of the 167 writing activities found in seventh grade textbooks, 75 percent were instances of responding to question, 23 percent were instances of problem formulation, and two percent were instances of project/report types of writing. In the eighth grade textbooks the researcher found 180 writing

activities. Of these 180 instances, 71 percent were instances of responding to a question, 28 percent were instances of problem formulation, and only one percent were instances of project/report types of writing. The median number of instances is 27 for grade seven texts and 23 for grade eight texts, a surprisingly low number. If a teacher uses every writing activity in the text students will have less than one writing activity per week. Since the majority of writing activities found in the textbooks were classified as a response to a question, or category one, students are not given the opportunity to communicate mathematics through writing activities in their textbooks (Davison & Pearce, 1988).

The researcher also considered the types and number of writing activities found in teacher's editions combined with student textbooks. This data is presented in Table 2.

Table 2

Number of Instances of Writing Activities in the Student Texts and Teacher's Editions Combined

	GRADE 7 Type				GRADE 8 Type			
Series	1	2	3	***Total***	1	2	3	***Total***
A	25	27	14	66	17	22	4	43
B	9	31	6	46	5	20	1	26
C	57	25	4	86	58	31	3	92
D	75	11	3	89	53	8	6	67
E	5	22	16	43	4	33	18	55

In both the seventh and eighth grade textbooks, differences existed in the number of writing instances in all three categories. In seventh grade it was found that 52 percent of the writing instances were a response to a question, 35 percent were instances of problem formulation, and 13 percent were instances of project/report types of writing. In eighth grade it was found that 48 percent of the instances were responses to a question, 40 percent were instances of problem formulation, and 11 percent were instances of project/report types of writing. The median of instances is 66 for seventh grade and is 55 for eighth grade. This represents approximately two writing instances per week during the school year. However, this fact is based on the assumption that every teacher would implement all of the writing activities suggested in the textbook (Davison &Pearce, 1988).

The research of the five textbook series concluded that there were very few writing activities, and there were very few instructional tools for teachers. In addition, the writing opportunities suggested were not real life problem situation and students found no relevance in these types of problems. Student textbooks and teacher's editions need to be updated and be provided with numerous writing activities that require longer project/report responses. At this time, students will have a greater understanding of mathematics and will be able to communicate using mathematical language more effectively (Davison & Pearce, 1988).

Another study was conducted at St. Charles High School, in May 1994, to determine the ability of writing skills of high school students. Data was collected from 200 randomly chosen high school students of all ages, to study two main parts of writing which include: the ability to communicate the purpose of a situation or problem and the ability to organize the integral parts

of a writing piece. The researcher provided each student with a prompt describing a real life situation.

The students task was to communicate the purpose of their writing piece and to organize the writing piece with clarity and accuracy. The researcher then assessed the students writing pieces by using a rubric made up of four main categories: needs help, marginal, acceptable, and exemplary. Of the 173 writing samples that stated the purpose of the writing piece 61 percent needed help, 31 percent were marginal, eight percent were acceptable, and zero were exemplary. It was found that the results of the organization part of the writing piece had similar results. Of these writing samples 44 percent needed help, 45 percent were marginal, 11 percent were acceptable, and none were exemplary. These results indicate that writing at the high school level needs improvement. Students need to be provided with writing opportunities across the curriculum. As the number of writing opportunities increase the number of acceptable and exemplary writing pieces should increase. Writing in any discipline provides for effective communication, awareness, and understanding of new concepts and ideas.

Causes from the Literature

The literature states that mathematics students seldom write what they are thinking (LeGere, 1991). In a study by Davison and Pearce (1988), data on the amount, kinds, and uses of writing in mathematics classes were collected. It was found that student writing was infrequently used as an instructional technique. In fact, the median number of writing activities in a classroom represented less than one writing activity every two weeks. "Writing activities, such as transcribing symbols to written language and writing story

problems, were found to be seldom used" (Davison & Pearce, 1988, p. 493). It was also discovered that prewriting and revision were rare or non-existent. Without sharing, modeling, or revising written work, students are being tested about their writing assignments rather than being instructed. This study concluded that mathematics teachers made relatively little use of writing activities. The few teachers who had students use writing activities did not use them to develop a better understanding of mathematics.

When designing lessons and structuring a mathematics course, most teachers rely extensively on the textbook. Another study by Davison and Pearce (1988) which examined the nature and extent of writing in five textbook series, concluded that textbooks "contained few writing activities, very few longer writing tasks, little or no instructional support, and no assistance for teachers on how to use writing in their mathematics classrooms in either the form of explanation or additional references" (p. 498). Without the support and assistance of writing as an instructional method of teaching, teachers are easily frustrated and tend to have a poor attitude towards writing activities in their classroom. In addition, textbooks need to be revised to give students the opportunity to read the text. Often, students avoid reading the text and get by with methodically working exercises (Keith, 1988).

Students often think that success in a mathematics class means good grades. Recent research, however, indicates that success or failure in mathematics depends on much more than the required knowledge of mathematical content. (Garofalo, 1989). Students believe that mathematics is just memorizing rules and plugging numbers into formulas. They view the teacher as the authority figure who is accountable for passing on mathematical knowledge to students (Miller & England, 1989). In a study by

Brown et al. (1988), students believe that mathematics is one of the most important disciplines used in society but the least important for them personally. There is an emerging view from secondary students that mathematics is just a process with certain rules. Seventy-five percent of the students in the study believe that they understand what is going on in their mathematics class (Brown et al., 1988). These results conflicted with assessments for understanding mathematical concepts. The study concluded that most secondary students have the knowledge of basic mathematics skills but are "not able to apply this knowledge in a problem-solving situation, nor do they appear to understand many of the structures underlying these mathematical concepts and skills (Brown et al. 1988). These beliefs, views, and attitudes of secondary students may be caused by under utilizing alternative instructional techniques such as writing activities in a mathematics classroom.

Writing and communicating using mathematical language appears non-existent in many secondary mathematics classrooms. Failure to introduce writing activities to students may be the cause of poor communication skills. The attitude of a teacher has an impact on student learning. If a teacher is reluctant to use instructional tools to improve student writing skills, then there will not be a positive improvement in the students' ability to communicate mathematically, and apply mathematical concepts. This may lead to students' failure to see the relevance in mathematics, hence contributing to low motivation and interest in the subject.

Probable Cause (Site Based)

In order to document the lack of verbal and written skills of Algebra and Pre-Algebra students, surveys were given to students at Addison Trail High School and St. Charles High School (Appendix A), parents (Appendix B), and teachers (Appendix C). The survey documented such topics as attitudes towards mathematics; types and quantities of writing assignments in the mathematics classroom; and changes in the mathematics textbook, teacher instruction, and curriculum. Teacher checklists and student interviews documented the verbal skills of students and their ability to use mathematical terminology accurately.

There were 40 students involved in this process over a four week time period. They were given a survey during the first week of school to aid in the process of collecting data. It was found that 50 percent of the students think that mathematics is "just OK," and ten percent stated that they strongly dislike mathematics. Data has also been collected at St. Charles High School to determine students' attitudes throughout their schooling years, as far back as kindergarten and it was found that students' interests and attitudes towards mathematics declines during the high school years. Administrators suggest that high school students no longer see the importance of mathematics or how it relates to real life applications. Not only is there no connection among mathematics and other disciplines, but students lack the motivation and desire to understand and communicate mathematics.

In addition to students' attitudes toward mathematics, the results indicate an attitude towards writing in general. Forty-one percent of the students do not like to write. This data is presented in Table 3.

Table 3

Student Survey Results (n = 40)

Attitude Towards Mathematics	Strongly Dislike	10%
	Dislike	17%
	Just "O.K."	50%
	Like	20%
	Strongly Like	3%
Attitude Towards Writing	Dislike to Write	41%
	No Opinion	15%
	Like to Write	44%
Types of Instruction	Lecture	8%
	Group Work	15%
	Combination	74%
	Self-Assessment	3%
Types of Homework	Odds/Evens in Text	19%
	Worksheets	25%
	Combinations	48%
	Written Assignments	8%

Students feel that writing does not belong in a mathematics classroom, and should only be taught during English class. This close-minded attitude may be a hindrance towards writing and communicating to understand mathematics.

The data also revealed that 97 percent of the students learn mathematics in one of the following teaching strategies: lecture, group work, or a combination of these two methods. Students were also asked to name the types of homework assigned to them in mathematics class. It was found that 92 percent of the students are assigned drill and practice problems such as odd or even exercises or a drill and practice worksheet. A startling statistic is that only eight percent of the students are assigned writing activities. These

responses indicate that writing assignments are not assigned on a regular basis nor are they being encouraged by the teacher.

Parent surveys were distributed at the beginning of the school year to determine parents opinions and attitudes about mathematics and writing. Too often, parents do not like mathematics or they view themselves as poor mathematics students at one time or another and use these ideas as a crutch to explain their child's lack of abilities in mathematics. Encouragement and support from parents at home can be a crucial element in the learning process. There were 60 parents who responded to a survey given by the teachers during the first week of school and of those surveyed, 66 percent ranked their own mathematics skills as average or below average. In other words, these parents know arithmetic and can process mathematical information involving fractions and percents. Seventy-four percent of the parents feel that mathematics is very important, needed on a daily basis, and is essential in life.

The researcher also inquired about parent attitudes towards reading and writing. It was found that only 45 percent of the parents encourage their child to write daily, while 93 percent encourage their child to read daily. The results suggest that parents believe mathematics is important for life skills but they are not willing to encourage the methods or may not know how to encourage the methods needed to understand mathematics and thus these conflicting attitudes of parents may be related to the poor attitudes that students have toward mathematics. The parent survey also documented the parents perception of the types of assignments given to students. In grade school, 77 percent of the homework assignments were either worksheets or even/odd exercises from a textbook. In junior high, 73 percent of the homework assignments were of the same types as grade school. It was found that in

grade school and junior high that writing activities were assigned only 17 percent of the time. During grades three through five, seven percent of the parents believed that their child's teacher emphasized writing in the curriculum. Similar results were found during grades six through eight. Once again, these results suggest the majority of homework assignments continue to be drill and practice. Students are not given the opportunity to write about mathematics. The need for other types of activities is evident. Teachers are not encouraging other methods of teaching to learn mathematics; the mathematics curriculum needs to be updated to understand the connections among mathematics and real life situations.

There were 15 teachers at St. Charles High School and Addison Trail High School involved in a survey to document attitudes about writing in mathematics and views about writing activities in textbooks. This data is presented in Table 4.

Table 4

Teacher Survey Results (n = 15)

Average Number of Years Taught		23.5 yrs.
Currently Use Writing in Classroom	Yes	46%
	No	54%
Types of Writing	Definitions	7%
	Journals	7%
	Proofs	27%
	Short Answer	53%
Average Number of Years Writing Was Used In Class		4 yrs.
Willing to Use Writing	Yes	31%
	No	69%
Have Seen Changes in Texts	Yes	77%
	No	23%

It was found that the average number of years these 15 teachers have taught was 23.5. This data suggest that these teachers have seen a wide variety of teaching methods. Of the teachers surveyed, 46 percent use writing activities in their classrooms. The majority of these teachers defined writing activities as writing proofs in geometry or writing a response to a "explain" type of question. (Only one teacher defined writing activities as journals, small summary statements, and descriptive statements about the procedure of a problem.) The survey documented that 31 percent of the teachers were willing to use writing activities in their classroom and 77 percent have seen some changes in textbooks regarding writing activities. These results suggest that teachers have poor attitudes towards writing activities in mathematics. Teachers see more and more writing activities in textbooks, yet refuse to try

this new approach. Without the support of teacher with writing activities, students will not experience the use of writing to understand mathematics. Ironically, the majority of teachers, 85 percent, felt that writing activities would enhance a students understanding of mathematics. Yet the lack of writing activities and attitudes continue to be a cause of poor writing skills and understanding of mathematical concepts.

A teacher observation checklist was developed to aid in the documentation of verbal skills of Algebra and Pre-Algebra students. The checklist was comprised of two sections (Appendix D). The top section documented the verbal response of a student to a teacher directed question. The bottom section documented the verbal skill of a student who asked a question during class. Each section was divided into four parts, similar to a rubric type of assessment. These four parts included: terminology used correctly, terminology attempted, terminology not used correctly, and terminology not used at all. Each day for three weeks the teacher used this checklist to gather data on verbal skills. It was found that 13 percent of student responses used mathematics terminology, 25 percent attempted to use mathematics terminology, 37 percent used terminology incorrectly, and 25 percent did not use mathematics terminology. In addition, the study concluded that 18 percent of student questions were asked using correct mathematics terminology, 42 percent attempted to use mathematics terminology, 30 percent used mathematics terminology incorrectly, and 10 percent did not use mathematics terminology. These results suggest that less than 20 percent of the students can ask questions or respond to questions using correct terminology. If students can not talk about mathematics then students most likely do not fully understand mathematics. Students need to be able to listen

to read about, write about, speak about, reflect on, and demonstrate mathematical ideas to move toward a deeper understanding of mathematics (NCTM, 1989).

The final documentation of poor verbal skills was collected through student interviews. There were 22 randomly chosen students who participated in an interview sometime during the first three weeks of the school year. Each student was asked five questions (Appendix E) and the teacher documented the verbal responses during the interview. Once again a teacher checklist consisting of the same four categories as the last study, was used to document the student responses. Of the 110 responses, 11 percent used mathematical terminology correctly, 22 percent attempted to use mathematics terminology, 35 percent used terminology incorrectly, and 32 percent did not even attempt to use mathematics terminology. These results indicate that less than 50 percent of student responses use mathematics terminology to explain mathematics. If mathematics terminology is not used, mathematical concepts are not understood. Students need to have the opportunity to practice speaking about mathematics. Educators and parents must provide an environment for students to engage actively in mathematics. Participation both active and verbal can lead to a deeper understanding for mathematics and its use in real life situations.

Chapter 3

THE SOLUTION STRATEGY

Review of Literature

Supporters of writing in mathematics (Johnson, 1983) believe if students can write clearly about mathematical concepts, then they probably understand those concepts. The five types of writing categories identified by Miller, 1989, include: direct use of language, linguistic translation, summarizing/interpreting, applied use of language and creative use of language. The first type is simply copying information either from the textbook or from teacher notes. The second type, linguistic translation is the translation of mathematical symbols into words. Summarizing/interpreting is paraphrasing and making personal notes about materiel from texts or other sources. The fourth category, applied use of language uses situations where mathematical ideas were applied to a problem context. Finally, the fifth category creative use of language is designed to use written language to explore and convey mathematically related information.

Writing can cause students to analyze, compare facts, and synthesize relevant material (Miller & England, 1989). These types of writing can be kept in a mathematics journal or mathematics log and both types of writing are very similar. They are designed to help students reflect on new concepts. Writing about a topic requires students to think about a topic, focus on and internalize important concepts, and to some degree to make those concepts

their own. An article by McIntosh (1991) states that learning logs should be used on a daily basis. Teachers can develop three different types of logs for students to use: "how-to's," "definitions," and "troubleshooting". The first type "how'-to's" should be used for explanations of procedures. For example, students could use this type of log to explain the process of changing a fraction into a decimal. The second type of log, "definitions" is designed for the students to write definitions in their own words. An example of this type of log would be to have the students write in their own words the meaning of perimeter. The third type of log is "troubleshooting." This log will force students to specifically explain errors that they or their teacher have identified (McIntosh, 1991). This process of using learning logs allows for simultaneous student thinking, closer examination of work by teacher, more precise encouragement, and leaves work available for later discussion.

Journals are considered to be similar to learning logs with the exception that they are more communicative with less formal writing (McIntosh, 1991). The journal is more of a diary; three to about seven minutes should be allowed on a daily basis for students to write in their journals (Nahrgang & Petersen, 1986). The journal is designed to open the communication between students and between a student and a teacher. It does not have to be collected but must be read and responded to (Abel & Abel, 1989). The journal has basically two functions: 1) it allows students to go at their own rate to understand mathematical concepts in terms of their own experiences, and 2) it also functions as a diagnostic tool, which can reveal confusion or show misunderstandings' students have (Nahrgang & Petersen, 1986). A suggested way to present journal writing is to use the information sheet in Appendix F. The teacher needs to inform the students that they need to write in their

journal. The writing that can either be grammatically perfect or written in phrases; it should contain new concepts, profound thoughts, wonderings, reflections and questions. Journal writing should be done anytime, including after class, but especially when an insight or question forms. The benefits of using journals are: enhanced learning, awareness of students learning, and knowledge of what students are thinking (McIntosh, 1991). The more students use their journals to write as a place where they can think on paper, not just report already formed ideas, the more they will take advantage of the potential of writing as a tool for learning and growth (Borasi & Rose, 1989).

Another tool for learning and growth is cooperative grouping. There are several distinct forms that can be identified, however all agree with the basic premise that in today's society, students need to work together. More frequent giving and receiving of explanations take place when students of different abilities work together cooperatively (Artzt, 1994). The verbal communication of mathematics allows students to become actively involved in learning. To explain a mathematical idea to one's peers, students must have a greater understanding of the material than that which is required merely to produce an answer on a worksheet. Developing a positive attitude towards mathematics aids in the student's ability to learn mathematics. Research indicates that cooperative learning experiences promote improved attitudes (Artzt, 1994). Cooperative learning has been compared to sports, where athletes know that the whole school is rooting for them and they exert their best efforts (Slavin, 1990). This is compared to a traditional classroom, where students are in competition with each other for grades and attention. It is much easier for all students to be motivated to learn when they have the proper support system. That support system is cooperative learning. Small

group cooperative learning provides social support, opportunities for success, group discussion of problems, student tutoring, opportunities for talking, listening, explaining, and thinking with others (Davison & Pearce, 1990).

Cooperative learning is basically a simple process, but different from traditional learning and traditional classroom operation (Foster, 1993). In the cooperative classroom, the curriculum is organized around student tasks. There are six essential steps the teacher must take to begin cooperative learning. First, the teacher should arrange the room to allow students to face each other when working in groups. This encourages students to help, share, and support one another (Bellanca, 1992). Second, choose the number of students to be in each team. The recommended number as suggested by Kagan would be four, chosen by the teacher, or at random and changed every six to eight weeks (Foster, 1993). Third, make the groups, with mixed ability and ethnicity. Fourth, prepare students for cooperative work, by teaching social skills. This should be done over a period of time. Learning will not be productive unless members of the group learn skills of leadership, decision-making, trust-building, communication, and conflict-management (Johnson, 1990). Fifth, plan teaching materials and instructions for cooperative groups. Materials and instructions need to be structured in a way that allows each student responsibility for the group work (Artzt, 1994). Group members need to be dependent on each other to complete the task. Sixth, explanation of the team task for the day is vital for learning (Foster, 1993).

One specific type of cooperative learning as developed by Slavin is Student Teams Achievement Divisions (STAD). Students are organized in teams, or groups, to help teach material, and encourage each other to do their best (Slavin, 1990). Students work together after the teacher's lesson but

may not help each other with quizzes. The teams are then given a score which is based only on a students own improvement. STAD is made up of five parts and the five components include: class presentations, teams, quizzes, individual improvement scores and team recognition.

Class presentations are the initial part where new material is introduced to the class. This is most-often a lecture-discussion conducted by the teacher. The only difference to this from a traditional lecture, is that this lesson is focused on the STAD unit (Slavin, 1990). Students realize they must pay close attention because doing so will help them do well on quizzes, which determine scores. In the second component teams are created from a cross-section of the class consisting of four or five students. The main function of the team is to prepare its members to do well on the quizzes. Teams are the most important part of STAD. Members are encouraged to do good for the team, and the team provides the peer support for academic performance that is important for learning (Slavin, 1990). Third, quizzes are given to individuals created to test the knowledge from class presentations. Students are not allowed to help one another. They are individually responsible for knowing the material. Fourth, individual improvement scores are calculated to give each student an opportunity to show improvement. Each student starts with a base score, determined by averages on quizzes, and a system is designed to give points to the team for improvement. Thus any student can contribute points to their team, but only if their work shows improvement. Finally, team recognition is given in forms of certificates or other rewards according to preestablished criteria.

A similar model is presented by Johnson and Johnson. It is also identified by five critical characteristics: face-to-face interaction, individual

accountability, cooperative social skills, positive interdependence, and group processing (Bellanca, 1992). Face-to-face interaction includes assisting, helping, supporting, and encouraging each other's efforts to achieve. There are cognitive processes and interpersonal dynamics that occur only when students get involved in explaining mathematics to each other. This includes orally explaining how to solve problems, discussing the nature of concepts being learned, teaching one's knowledge to others, and connecting present learning with past learning (Johnson, 1990). Individual accountability is to promote the fact that students must know that they cannot get away without doing work, and simply add their name to the work of their group members. Common methods to insure accountability include giving individual tests to each student and randomly selecting one group member's product to represent the group. Students must learn and frequently use required interpersonal and small-group skills. Cooperative skills such as leadership and communication must be taught just as purposefully and precisely as academic skills (Johnson, 1990). Positive interdependence is the perception that one is linked with others in a way that no one can succeed unless everyone does. It is created through a structure that includes a common goal, group rewards, and role assignments to encourage students to assist each other in completing the learned task (Bellanca, 1992). Group members need to reflect on how well the group is functioning. This group processing allows members to focus on maintenance, practice social skills, and receive feedback on participation in the group.

A third model of cooperative learning is presented by Spencer Kagan. His structural approach is based on the creation, analysis and application of content-free structures that cause students to interact in positive ways in the classroom (Bellanca, 1992). Kagan has developed structures that fall into

three main categories: In Turn, where students take a turn in a prescribed order Jigsaw, where each student has part of the information to study and teach to the others and Match-ups where the teacher structures student-to-student tasks, which create cooperative situations.

While all of these approaches to cooperative learning have their own unique attributes, no one approach is sufficient or superior (Bellanca, 1992). Cooperative learning is a necessary tool for teaching in the mathematics classroom. Students enjoy discussing mathematics with other students and they benefit from their interaction with other students as well as with the teacher (Artzt, 1994). Since each classroom is different, the teacher in a cooperative class must make cooperative learning their own, allowing for adjustments and refinements as the need arises. Any classroom that includes opportunities for students to work productively in small groups will create an inviting learning environment (Clarke, 1990).

Basically, any grading system, except the curve, can be used in a cooperative classroom. The types of appropriate evaluation are: oral as well as written, group as well as individual, essay questions as well as short-answer questions (Dees, 1990). Portfolios provide a unique way to incorporate these several different types of assessment into a self-evaluation tool. Self-evaluation is the greatest asset of portfolios (Frazier & Paulson, 1992). Portfolios also encourage ownership, pride and high self-esteem to students as a method to take charge of their learning. A portfolio is a record of learning that focuses on the student's work and reflection on that work. Material is collected through a collaborative effort between the student and teacher (Daws, 1993). There are many different ways portfolios are being used, but

mostly the approach can be thought of as the attempts to discover how students learn.

Some of the different types of portfolios include The Collection, The Showcase (or Display Portfolio) and The Teacher/Student Assessment Portfolio. The Collection is simply a folder that holds an accumulation of a student's work. The Collection Portfolio will by nature contain a wide variety of work because it is intended to be viewed by the student and teacher. This portfolio will then be used to create the other portfolios. The Showcase is a selection of work representing a student's progress and achievements and it can be presented at conferences or Open House. It is intended to be viewed by those the student wants to impress or the teacher wants to inform. It should contain work that is the student's best or work that shows growth over time. The Teacher/Student Assessment Portfolio is a collection of documentation including work in the Showcase Portfolio and tests and test scores, anecdotal records of observations and conferences, and anything else the teacher includes as documentation of the student's progress. This portfolio is not intended for public display (Jasmine, 1992).

In order to start a portfolio, of any kind, some area needs to be arranged to organize the collection. The teacher and students need to have access to a folder system, to included pieces for the finished product. The selection of items should be shared among the teacher and student. By allowing the student to include pieces of work that he or she feels are best or most important, gives ownership of the portfolio to the student. Each piece that is included should also have a reflection attached. The reflection is crucial to the self-evaluation aspect of the collection. The student should also include reflection on their progress in general, over the year or part of the year (Jasmine, 1992).

Math portfolios are a wonderful way for students to celebrate their learning (Knight, 1992). They allow for traditional mathematics communication of numbers, symbols, graphs, and tables as well as individual projects, mathematics journals, descriptions of difficulties and/or successes, as well as essays reflecting on progress and growth (Jasmine, 1992).

Project Outcomes and Solution Components

As a result of increased instructional emphasis on writing and speaking using the mathematical language, during the period of September 1994 to January 1995, the targeted freshman and sophomores from one pre-algebra class and one algebra class, will increase their ability to write and speak mathematically, as measured by teacher observations and teacher assessments.

In order to accomplish the terminal objective, the following strategic procedures are proposed:

1. writing activities will be assigned a minimum of three times a week using both journals and logs.

2. students will be taught group skills for cooperative learning to be done a minimum of twice a week.

3. student will be instructed on the use of learning portfolios and will create one to document their learning progress.

Action Plan

The teachers will implement three main strategies to aid students learning to speak and write using the language of mathematics. The three strategies are: journal writing, cooperative learning, and portfolio assessment and will be implemented from the period of October 3, 1994, to January 20,

1995. Each strategy was chosen with a specific purpose in mind. Journal writing was chosen for its most obvious benefit, of encouraging student to write and express their ideas more often in a mathematical frame. Cooperative learning was chosen to encourage students to communicate verbally while problem solving with their peers. The portfolio was chosen to help students see growth in both their writing abilities as well as in their mathematical abilities. By combining all of these strategies the teachers hope to increase student confidence in mathematics; therefore raise their students' self-esteem.

Each student will create a journal in class that consists of a title page (Appendix G) and approximately 20 blank pages for writing. The students will then have an opportunity to write in their journals at least three times a week for approximately five to seven minutes each time. The teachers plan to direct the students' responses in the journals by giving the students writing stems to respond to, as opposed to free response. Some of the suggested writing stem include: I like (or don't like) mathematics because. . . , I learned today that. . ., Something I still don't understand is. . .. This part of the journal will include "how to" do certain procedures as well as "troubleshooting" frequently missed problems. Most journal entries will not be graded but responded to with specific comments from the teacher, to help the students feel that their writing is important and to direct the students to a deeper understanding of the material presented. The sections of the journals that will be graded will use a rubric as in Appendix H. Teachers will also direct students to keep a "definitions" section of the journal to help them understand the meanings of mathematics terms, and to recognize the different ways some terms are used in mathematics compared to everyday terminology. The purpose of the journal is to provide opportunity for students to write, to improve their writing skills, to increase

their understanding of mathematics and its connections to the real world and to increase students' self-esteem and their attitudes towards mathematics.

The second planned strategy, cooperative groups, is designed to help students learn to work together to solve problems mathematically using verbal communication skills. Groups will be established using class ranking, where high ability students will be matched will low ability students. The groups will contain four to five students of mixed race and sex. The teacher will establish a base score for each group member, which will then be used to determine team improvement scores. Each group member will be assigned responsibilities: manager, time keeper, encourager, recorder and reporter to help teach social skills. These responsibilities will be rotated frequently. At least twice a week student will work in their cooperative groups. The teacher will create different activities to aid in learning the new material, including strategies of pair-share, expert corners, and group discussions. Each activity will stress components of cooperative learning, will utilize higher order thinking skill, will unite the group members yet insuring individual accountability, will develop social skills, and provide an opportunity for reflection on group work. The teacher will give students quizzes on material learned through cooperative groups, then establish a group improvement score for rewarding successful groups. The scores will be established based on the amount of improvement each member shows compared to their base score. These activities are to be done in class to improve interpersonal and social skills and to practice using mathematical language.

Each student will be responsible for creating a portfolio with a creative cover and will contain a table of contents and tagged items. Both the student and the teacher will have the opportunity to select items to be included.

Portfolios will be kept in the classroom. Each student will select items for their portfolio including: at least two journal writings, two quizzes, and one project. The items will then be tagged with a written explanation of why they were chosen. Portfolios will be self-assessed, and peer-graded as well as evaluated by the teacher. The teacher will provide time in class for students to work on their portfolios. Additional time may be used outside class for completing individual projects. The portfolios are important to allow students to see growth in writing and understanding of mathematics.

Methods of Assessment

In order to evaluate that the strategies suggested are successful, the teachers will monitor and grade random selection from student journals. They will also give post-intervention surveys and interviews. This will provide the teachers the opportunity to follow their students progress in learning mathematical concepts as well as communication skills. The teachers should also be able to observe attitudes as expressed by the students about writing and about mathematics. The students will also give an oral presentation in cooperative groups. This cumulative project will allow the teacher to monitor the effectiveness of the cooperative groups and the use of verbal communication.

Chapter 4

PROJECT RESULTS

Historical Description of Intervention

The objective of this project was to increase students use of the mathematical language through speaking and writing. Implementation of three main strategies was planned and applied: stage 1, journal writing; stage 2, cooperative learning; and stage 3, portfolio assessment. It began on, October 3, 1994, and was concluded on, January 20, 1995. The plan was to introduce one stage at a time allowing students the opportunity to become familiar and comfortable with that stage before moving onto the next stage; original plan was modified because of time constraints and very little emphasize was put on portfolio assessment.

The time constraints were due to interrupted classes from the school related activities, as well as from teacher commitments. Assemblies during class time, disaster drills, field trips, counselors and dean interventions, as well as the normal holiday schedules and homecoming activities all caused interruptions. In addition, St. Charles High School was temporarily evacuated due to a gas leak. Teacher commitments included organizing school functions, student council responsibilities, conventions, workshops, and administrative meetings.

Journal writing, the first stage implemented, was used to make students think and practice writing about mathematics using mathematical

terms. Students were to make entries three times a week. They were each given a booklet to keep and time was allowed in class for the writing. Some initial problems arose with the journal writing, especially in the Pre-Algebra class.

This Pre-Algebra class consisted of 18 students, three of whom were learning English for the first time. These students could not understand most of what had been given to them in the way of directions or explanations during the implementation of the project. Two of these students were Hispanic; however another Hispanic student was able to assist them with translations. The third student was Polish with a strong mathematical background; without the language barrier he would have been in Algebra I. This class also had two students that were receiving help in Special Education for part of their day and one student being tested for Special Education. There was one addition to the class at the end of October, a student who was moved down from Algebra 1 and a student who was expelled from school in January. There were not as many diverse problems with the Algebra class, which consisted of 22 students, from an upper-middle class background.

The teachers anticipated negative reactions towards writing in mathematics class, but hoped that student attitudes would changes over the course of the intervention. Exposure to many writing activities enables students to learn the benefit of thinking mathematically. At first, students resisted the idea of writing in mathematics class. They believed it should only occur in their English classes. Some of their responses to writing in mathematics class included: *Why do we have to do this?; ...writing in math class is so stupid...; I don't see the point of writing in this class...; Why do we have to do all of this busy work?; ...we write in English, we shouldn't have to write in this*

class too... The classes discussed the importance of communication in everyday life experiences and how the effect of writing in mathematics could affect communication skills in other areas. It was approximately one month after the intervention took place for students to accept the idea of writing in their mathematics' class. There were three types of journals' students responded to: an explanation of how to do a procedure, an example of where or how this is used in real life, and as a reflection on how they were learning. See Appendix I.

During the first month it seemed important to reinforce students' writing by modeling writing in class and giving immediate feedback in class on what had been written. The first writing activities proved to be a learning experience for both students and teachers. The first journal entries were not graded, since they were being used as a learning tool. After a month, the journals were graded as: completely answered the question, or, did not answer the questions. Toward the end of November, journals were graded according to the rubric presented in Appendix H. All journal entries were read and responded to by the teacher. Some journals were shared during class, and others were used as examples to demonstrate what was an appropriate response and what were an inappropriate response.

The second strategy was cooperative learning. Cooperative learning was used to teach social skills and verbal communication skills. Base groups consisting of four students were assigned at the beginning of the year and changed after each nine week grading period. Each group consisted of students with different math abilities and gender. Originally cooperative learning in base groups was to occur twice a week, to allow students the opportunity to talk with one another about how to complete a problem, about a question that

remains' unanswered or to provide feedback and encouragement. After three weeks this was modified to allow increased partner work on a daily basis. Time, with partners, was increased to 15 minutes each day to provide support in communicating mathematically and time spent, in their base groups, was decreased to once a week or once every other week. Students had more opportunities to talk about mathematics when they were in groups of two rather than four. In addition, these groups of two changed more frequently, than the base groups, allowing students the chance to get to know one another more quickly. The original plan to assess cooperative learning was to use base scores. Since the base groups changed in number and in focus, the base score assessment was not relevant. Instead the teachers used more traditional forms of assessment, such as paper-pencil quizzes and worksheets.

Teaching social skills was one of the beginning tasks of the groups. This process took longer than anticipated. Students were taught skills in listening, paraphrasing, cooperating, sharing, and team building using non-mathematical models. Lesson plans devoted to these skills can be found in Appendix J. Along with these social skills mathematical skills were developed. Students worked in partners on "Think-Pair-Share" activities, such as: naming rational numbers or identifying types of equations as linear, quadratic, or absolute value and students were dependent on each other to complete worksheets. Occasionally partner quizzes were given. First students worked on their own quiz then were given 15 minutes to work with an assigned partner to compare and assist each other. Jigsawing, one other major type of cooperative learning strategy, was used. Students would be assigned a series of problems to complete on their own. They would then meet with student who had done the same problems, to check for accuracy. Finally, they would teach others in

their base group the problems they did. All of these strategies enhanced students' abilities to verbalize mathematics. As the project progressed, students were much more comfortable working with their partners learning about mathematics, and often asked if they would be able to work with their partners on daily assignments.

Teacher assessment was the third and final strategy implemented. As students became more comfortable with writing about mathematics, tests were altered to included written sections. For example a test on linear equations previously contained problems that asked students to solve for the variable x and to graph a line. The new tests now included questions that asked students to explain how to do find the solution x, and what does that solution mean mathematically. See Appendix K, which contains test question examples. Assessments were also used for group work where students had to evaluate how well they worked with each other by answering the following questions: 1) This person is willing to help and explain when asked; 2) This person does their share of group work; 3) This person gives logical explanations as opposed to saying, "Just because." or "Believe me."; 4) This person contributes to learning and the sense of enjoyment that should come from working in groups. For a detail worksheet see Appendix L. The portfolios became a collection of graded writing assignments and quizzes/tests not a student selected evaluation tool. It was these three strategies of journal writing, cooperative learning, and assessment that were implemented to observe student communication about mathematics.

Presentation and Analysis of Results

The emphasize of the project was on communicating mathematics. The first focus was in the form of written communication, student journals; journals themselves became an assessment tool to document students' ability to write mathematically. The teachers discovered that teaching students to write mathematically was a larger task than they had envisioned. Pre-intervention journals began with simple prompts which were read and respond to. For example, from a journal dated, October 3, two prompts were given: "I study for math by ..." and " I like (or don't like) math because..." Students were given ten minutes in class to respond to both prompts. While the students reflected, the teacher observed and made some of the following notes: *...a few students are actually writing, most don't seem to be taking this seriously. I wonder if for that first question they are going to respond with I don't study...* A typical student response was *...reviewing through notes, going through quizzes. I also look through the homework...* Only half of the students responded to the second prompt and these were varied with the exception of homework. *I don't like math because we have homework in it everynight. But other then that its O.K.* another response was *I think math is O.K. some problems are hard and some aren't. I normally always have problems in solving problems. I have also realized how important math is.* The teacher responded to each entry with a personal note, some of which were longer than what the students themselves had written.

The researchers discovered that students needed very specific directions and very specific questions to answer. For the most part the students did not seem able to motivate themselves through a piece of writing. With these changes in mind alterations to the prompts were given, and the teacher spent

time teaching the students what was expected. Some student journals were read in class as examples that could use improvement. In response to the following prompt: Explain how to do the following problem: -9m + 7c + 4 -3c -2c -5m. one student responded: *You would take -9m + -5m = -14m 7c + -2c + -3c = 2c. You would add them all together. Then all together your answer would be 14m + 2c + 4.* This was not a good example. Even thought the mathematics was done correctly, no explanation was given to the process used to determine it. The directions clearly stated the student was to explain the problem not to just work it out. To compare for the class, a well-worded student response was then presented: *First you check to see if there are any negative signs. Since there are you change-change, the sign and the sign of the number that follows. So: -9m + 7c + 4 + -3c + -2c + -5m. Than you add the "milk" together, or the "m's", and separately the "cookies" or the "c's" and finally the number that is by itself. Your final answer is -14m + 2c + 4.* It was emphasized again to the students that they needed to explain what they were writing about and not just work the examples. Journal responses were often times definitions of mathematical terms. It was hoped by asking students to define terminology in their own words that they would have more meaning and therefore have a greater chance of being used correctly. In one example students were asked to define exponents, a typical response follows: *an exponent is the number that is to the right of the big number and the exponent is the little number. A exponent tells how many times you are supposed to multiply the base (big number) by itself. Exponents can also be used with letters (variables). Example:* $4 \cdot 4 \cdot 4 \cdot 4 \cdot 4 = 4^5$ *and* $2^3 = 2 \cdot 2 \cdot 2$. The journal was used to help clarify, or correct common mistakes. In the following example pre-algebra students were asked to explain why 2^3 did not equal 3^2. This is a common problem for many students that

'forget' the correct procedure and multiply the base number by the exponent. One student simply replied *Because* 2^3*equals 8 and* 3^2*equals 9.* While this student answered the question correctly it was hoped more of a detailed response would be given, as the following student replied: *The reason* 2^3*does not equal* 3^2 *is because you are not supposed to multiply the two numbers together, because if you did you would get 6 and they equal the same. In a problem like this you are supposed to multiply the big number (base) by itself as many times as the little number (exponent) is.*

The prompts continued to become more defined and the students learned to accept responsibility for gathering parts of the data. This is evidenced by the prompt "How do you know from the coordinates of a point which quardant contains the point?" Students responded in the following ways: *...because I have to know that Quardant I is (+,+); Quadrant II is (-,+); Quadrant III is (-,-); and Quadrant IV is (+,-).* ... and *...you look at the 2 numbers. let's say (2, -4), it's in Quadrant IV. You go to the 2 which is positive and then look for the -4 which is negative. You follow their lines and where ever they meet is where the point is. You can also check the signs of the Quadrants.*

Students also had the opportunity to express opinions and feelings about the class. Some responses to the prompt "What advice would you give to a new Algebra student" include: *Do the homework good and be sure you listen; I'm not sure, I'm a new student. I was only here for two weeks first semester, I'd suggest doing all of the assignments.* and *Good Luck and do all the work. If you don't know how to do something ask the teacher.*

A survey was given to students prior to intervention and the same survey was given at the end of the intervention to compare results and attitudes of students. Post survey results indicated that 63 percent of the

students think that mathematics is "Just O.K.". There were still five percent of those surveyed who strongly dislike mathematics, see Table 5.

Table 5

Student Attitudes Reflecting Mathematics and Writing

n = 40

	Pre-Intervention	Post-Intervention
Mathematics is "Just O.K."	50%	63%
Dislike Mathematics Strongly	5%	5%
Like to Write	59%	65%

Results also indicate that 65 percent of the students like to write. In the pre-intervention survey only 59 percent of the students stated that they like to write. It appears through more frequent writing activities that student attitudes towards mathematics and writing have improved.

The next section of the survey reflected how students learn mathematics and the type of homework problems they were assigned. From this survey the researchers observed that 100 percent of the students were learning mathematics through the following teaching strategies: lecture, cooperative learning, and writing assignments. Before the research project, only 8 percent of the students were assigned writing assignments. This shows a growth of 92 percent over a four month period.

In order to assess student's ability to verbally communicated a teacher checklist was used before and after the intervention. Students were assessed

in the following two areas: student's response to a teacher directed question and students' questions asked in class. This data is presented in Table 6.

Table 6

Teacher Checklist of Student's Verbal Communication Skills

n = 40

Responses to Teachers' Questions	Pre-Intervention	Post-Intervention
Terminology Used Correctly	13%	15%
Terminology Attempted	25%	40%
Terminology Not Used Correctly	37%	35%
Terminology Not Used	25%	10%

Student Initiated Questions	Pre-Intervention	Post-Intervention
Terminology Used Correctly	18%	23%
Terminology Attempted	42%	47%
Terminology Not Used Correctly	30%	23%
Terminology Not Used	10%	7%

Before the intervention 25 percent of the students' responses did not use mathematical terminology, 37 percent of the students' responses used mathematical terminology incorrectly, 25 percent of the students' responses attempted to use mathematical terminology, and only 13 percent of students' responses had used mathematical terminology correctly. Post intervention results include the following: 10 percent of the students' responses did not use

mathematical terminology, 35 percent of the students' responses used mathematical terminology incorrectly, 40 percent of the students' responses attempted to use mathematical terminology, and only 15 percent of students' responses had used mathematical terminology correctly.

The intervention appears to have improved the students' ability to verbally communicate using mathematical terminology. Prior to the intervention more than half of the students either used mathematical terminology incorrectly or did not even attempt to use it. This data may suggest that students were never asked to speak using mathematical terminology. Increasing the opportunities to verbally communicate using mathematical ideas was part of the intervention which may contribute to the improvement of verbal skills.

Another assessment of verbal communication was a student interview and it was conducted both before and after the intervention. The interview contained five questions, see Appendix E. The mathematical terminology increased throughout the intervention as seen in Table 7.

Table 7

Responses to Student Interviews (n = 22)

	Pre-Intervention	Post-Intervention
Terminology Used Correctly	11%	15%
Terminology Attempted	22%	30%
Terminology Not Used Correctly	35%	42%
Terminology Not Used	32%	13%

Prior to the intervention, student interviews revealed that 67 percent of the students either used mathematical terminology incorrectly while speaking or did not use it at all. The results also indicate that 22 percent of the students attempted to use mathematical terminology while speaking and only 11 percent use mathematical terminology correctly. Post intervention results revealed that only 13 percent of the students were not using mathematical terminology while speaking. Other results include the following: 42 percent of the students used mathematical terminology incorrectly, 30 percent of the students attempted to use mathematical terminology, and 15 percent of the students used mathematical terminology correctly. Once again, these results suggest an improvement in students' ability to verbally communicate using mathematical terminology.

Conclusions and Recommendations

Based on the presentation and analysis of data on student's written and verbal communication skills, it was found that there was improvement in the usage of mathematical language. By increasing the number of writing activities awareness of mathematical terminology was brought to students. In the past students did not use, or attempt to use correct mathematical language. Students were allowed to learn mathematics without using the appropriate language. Part of this reason may have been that the language was not emphasized in class by the textbook or by the teacher. Throughout the intervention students had many opportunities to practice writing using mathematical terminology. As the writing improved, confidence about what was being written was also increased. This may be the causes of improved attitudes towards both writing and mathematics.

A secondary outcome of this research project was the students understanding of mathematics also improved. Prior to the intervention students showed that they did not understand mathematics in their journal writing by presenting incomplete or inaccurate response to the given prompt. At the end of the intervention student responses consisted of paragraphs that could accurately describe and explain the given problem using correct mathematical terminology. When the intervention began it was a rare occasion that a prompt was given that did not need explanations about how to respond or answer it. As the intervention progressed, students were able to take a prompt, research it if necessary, find the correct vocabulary to use and respond without any additional help from the teacher.

The analysis of data on verbal skills showed an increase in the students ability to talk mathematically. In the past students were not able to ask questions about a concept using the correct terminology. They also had difficulty responding to questions asked by the teacher or other students. In addition student surveys suggest practicing verbal skills in cooperative groups allowed students the opportunity to communicate with each other on a regular basis. This increased their knowledge of mathematical vocabulary.

Increasing the frequency of writing activities in a mathematics classroom can have a positive affect on student writing and understanding of mathematics. The researchers recommend that this chosen intervention should continue with some modifications. It will be helpful for future researchers to collect base line data on student's journal entries. This information could then be used for comparison data and to show growth in writing. Assigning writing activities on a consistent basis informs students that these activities are a required element of the course and will help them see

the benefits of learning mathematics through writing. By sharing journal responses with their peers, in cooperative groups, students have the opportunity to improve their verbal skills and to help one another learn . In addition, many journal entries become an assessment tool simply by the nature of what the students are writing. The journal allows students to explain how a procedure is accomplished through their writing. The teacher can judge if the student comprehends the concept by assessing the thoroughness of the explanation. Journal writings also offer the opportunity for students to reflect on their learning through expression of difficulties, triumphs, or somewhere in between. These efforts can be expressed in the form of quizzes, tests, self-evaluation, peer-assessments, and other writings which comprise a portfolio. Portfolios should be more than just a collection of journal writings, as the researchers used them. They should be designed as more of an assessment tool for teachers and students.

The researchers noted that time itself was an influencing factor. In four months, the pressure to accomplish three major tasks: journal writing, cooperative learning, and portfolio assessment, was difficult to achieve. With an extended period of time teachers may have a more positive attitude, which is a strong influence in the classroom. In conclusion, it is recommended that teachers keep an open mind and positive attitude towards writing in the classroom. Overall these methods will improve writing and speaking skills using mathematical language.

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Appendices

Appendix A

Student Survey

1. *What math course were you in last year?* _____

2. *What letter grade did you receive?*

   1st semester _____ 2nd semester _____

3. *How do you feel towards mathematics? (please circle)*

1	2	3	4	5
strongly dislike		its OK		strongly like

4. *Looking at past math classes, have you been instructed using:*

   a) lecture mostly
   b) group work mostly
   c) combination of a and b
   d) other specify_____

5. *What type of homework have you been assigned in the past?*

   a) odd of evens from the textbook
   b) worksheets
   c) combinations
   d) written assignments describing how to solve a problem.

6. *Approximately how often do you do math homework? How often homework in general?*

MATH	*General*
# of minutes per day _____	# of minutes per day _____
#of minutes per week _____	# of minutes per week _____

7. *How do you study for a math test. (please explain)*

8. a) *Do you ever ask somebody, beside your math teacher, about math?*_____

   b) *Who do you ask?*_____

   c) *How often? (be specific number of days, etc.)* _____

   d) *What **kinds** of questions do you need help with? (be specific)*

_____

9. a) *Do you like to write?* _____

   b) *Do you keep a journal?* _____

   c) *Have you done any writing activities in previous math classes?*_____

   If yes, please list what types. _____

_____

10. *Other comments:*

Appendix B

Dear Parents or Guardians:

Currently I am working on a Master's Degree through St. Xavier University. Part of my course work involves a research project. The project I will be working on will involve your child. Throughout this semester, I will be collecting samples of your child's work, such as homework assignments, test, quizzes, and journal writing. All of the information collected will be anonymous.

As part of my research, I am also collecting some data from you the parents/guardians. I am asking for your help. Please complete the enclosed survey and return it with your son/daughter by Thursday September 1, 1994.

Thank you for your participation, and if you have any questions about the project or your child's involvement please contact me. Ms. Hackett can be reached during 7:30 to 8:25 and 10:40 to 11:15 at 377 - 4787 and Mrs. Wilson can be reached during 9:30 to 11:20 at 628-3352.

Sincerely,

Kimberly Hackett
Theresa Wilson

(Appendix B - Continued)

Parent Survey

1. *Rate **your** math skills on a scale of 1 to 5*

low		average high		
1	2	3	4	5
basic skills • arithmetic • fractions		higher skills • percents • angle measures		advanced skills •calculus •accounting

2. *What is your own personal attitude toward math? Please explain.*

3. *How often do you see your child study math? How often do you see them do homework?*

MATH	*General*
# of minutes per day_____	# of minutes per day_____
# of minutes per week_____	# of minutes per week_____

4. *What kinds of math homework did you child do in (please circle)*

grade school: worksheets, writing exercises, odd/even exercises in textbook, self -assessment activities

junior high: worksheets, writing exercises, odd/even exercises in textbook, self -assessment activities

5. *How often does your child ask for help with their math homework?*

a) daily b) one or twice a week c) only on weekends

d) never e) other_____

6. *How many **written** assignments have been assigned to your child in their math classes that you are aware of?* (By **written** assignments we mean those that require students to describe or explain their thought processes or procedures.)

   a) none b) 1 - 5 c) 6 - 10 d) 11 - 20 e) more than 20

7. *In previous years of your child's education, approximately how many math teachers emphasized writing in their classrooms on a daily basis.*

   Grades 3 - 5 1 2 3 teachers

   Grades 6 - 8 1 2 3 teachers

8. *Have **you** ever experienced writing in a math class? If yes, explain your experience(s).*

9. *Do you encourage your child to (check appropriate)*

   _____ write on a daily basis

   _____ read on a daily basis

   _____ write and read on a daily basis

10. Other comments or opinions about writing in math.

Appendix C

Questions for Teachers

1. *How many years have you taught mathematics?*

2. *Do you use writing techniques in your classroom?*

3. *If yes, how often and what kinds?*

4. *How long have you been using writing activities?*

5. *Are you willing to use writing activities on a daily basis in your class? Why or why not.*

6. *Have you seen changes in textbooks regarding the use of writing in math? Explain.*

7. *What impact do you feel writing will have on understanding math concepts, if any?*

8. *What impact has writing had on student attitudes toward math?*

Appendix D

		Mon.	Tue.	Wed.	Thurs.	Fri.
RESPONSES	Terminology Used Correctly					
	Terminology Attempted					
	Terminology Not Used Correctly					
	Terminology Not Used					
QUESTIONS	Terminology Used Correctly					
	Terminology Attempted					
	Terminology Not Used Correctly					
	Terminology Not Used					

Appendix E

Student Interview Questions

(Use a tape recorder to help document responses)

1. If you were talking to a man from outer-space, how would you explain what a fraction is and how fractions are used in daily life.

2. Explain the procedure to add two fractions with unlike denominators.

3. What does percent mean?

4. Explain how you would be able to find the percent of your last test score.

5. Explain to my nephew, Bobby, who is in third grade, how to change a fraction such as $\frac{5}{6}$ into a decimal.

Appendix F

JOURNAL

1. **WHO** should write in your journal? - - You should

2. **WHAT** should you write in your journal?

   New wrods or new ideas or new formulas or new concepts you've learned

   Profound thoughts you've had

   Wonderings, musings, problems to solve

   Reflections on the class

   Questions-both anserable and unanswerable

   Writing ideas

3. **WHEN** should you write in your jounal?

   After class each day

   As you are preparing, reading, or studying for class

   Anytime an insight or question hits you

4. **WHERE** should you write in your journal?

   Anywhere-so keep it with you when possible.

5. **WHY** should you write in your journal?

   *It will record ideas that you might otherwise forget.

   *It will be worthwhile for you to read later on so that you can note your growth.

   *It will facilitate your learning, problem solving, writing, reading, and discussion in this class.

6. **HOW** should you write in your journal?

   In wonderful, long, flowing sentences with perfect punctuation and perfect spelling and in perfect handwriting

   OR in single words that express your ideas, in short phrases, in sketches, in numbers, in maps, in diagrams, in sentences

MY

MATH JOURNAL

Appendix H

Journals or Logs	***1***	***2***	***3***	***4***
Response	Did Not Answer the Question	Gave an Example, Not a Written Response	Written Response with some Knowledge	Written Response with Thoughtful Insight
Accuracy of Terminology	Not Used at All	Attempted, Not Used Accurately	Used with Few Errors	Used Correctly and Accurately
Organization	No Organization	Lack of Organization (Off-track at times)	Good Organization	Well Organized

Creative or Expository	***1***	***2***	***3***	***4***
Over-All Clarity/ Effectiveness	No Ideas, Very Little Effort	Has Some Ideas; Lacks Clarity and Structure	Has Good Ideas; No Major Errors	Great Ideas; Well-Written
Accuracy of Terminology	Not Used at All	Attempted, Not Used Accurately	Used with Few Errors	Used Correctly and Accurately
Organization	No Organization	Lack of Organization (Off-track at times)	Good Organization	Well Organized

Appendix I

Sample Journal Questions for Pre-Algebra

1. You work in a bank, and your boss wants you to explain to a new employee, how positive and negative numbers are used. Be sure to give examples.

2. Explain how you solve a word problem. What techniques you use to write the equation. Explain how to set up problem number 6 on page 106, but DO NOT solve it.

3. Explain why the product of 8 negative integers is positive and give an example.

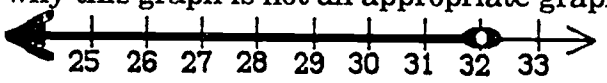
4. Define exponents and give examples.

5. Explain when you use fractions in real life and what operations you need to be able to perform using fractions. What are the most common fractions used?

6. You went to the deli and asked for four tenths of a pound of cheese. Explain to the person who works behind the counter what four tenths is. Give two common fractions that four tenths is between.

7. Tell me how you feel about this chapter, is it easy, hard or somewhere in between? Why?

8. Suppose there are fewer than 32 students in our math class. Explain why this graph is not an appropriate graph:



9. Describe a real life situation that can be described by the inequality ≥.

10. Explain how you can tell from the coordinates of a point which quadrant contains the point. How can you tell when a point will be on the x-axis, or y-axis?

(Appendix I - Continued)

Sample Journal Questions for Algebra 1

1. What is algebra? Describe some of its uses. How do you feel about math?

2. Design a problem which can be represented by a linear equation. Write the problem and represent it algebraically and graphically. Then solve it.

3. Look is a science book (or one of your science labs) and list at least 3 science formulas you have used or will use this year. Solve for each of the variables as we did in class.

   Example: $d = rt$ $\quad \frac{d}{r} = t \quad$ $\frac{d}{t} = r$

4. Describe a sport, hobby, or interest of yours and discuss the ways math may be involved. Be specific with examples.

5. a) Interview a friend or relative about his or her career. Ask about his/her use of mathematics in their daily routine. Ask for specific examples. Write a brief summary of your interview.

   b) What career are you considering at this point? How is math applicable in this field?

   c) If you could choose any individual to speak to our class on the use of math in their field, who would it be and why?

6. Contact at least 3 financial institutions (banks or savings and loans). Find the highest interest rate they have for a regular savings account (not CD's). Also quarterly, annually or other. Report your findings. Write a paragraph generalizing the information collected.

7. Find 5 words that share the prefix **POLY**. How are the meanings of these words related? How does the word polynomial relate?

8. How are you planning to study for your upcoming final? How will your approach to studying for your final differ from your approach to studying for other subjects?

Appendix J

Social Skill Lesson Plans

Teaching the skill of Team Building:

Step 1: Assign groups of four.
Step 2: Assign roles in the group, of encourager, manager, reporter, and recorder.
Step 3: Have the members brainstorm ideas for a team name and symbol.
Step 4: The reporter will then report to the group.

Teaching the skill of Paraphrasing/Sharing:

Step 1: From student base groups of four, sub-divide into two pairs: A and B, C and D.
Step 2: A interviews B while C interviews D.
Step 3: The interviewer asks questions and paraphrases, but does not elaborate or share personal data.
Step 4: Reverse roles: B interviews A while D interviews C.
Step 5: Share-around: Each person shares information about his/her partner in the group of four.

Teaching the skills of Listening/Sharing:

Step 1: Students should be paired up, partner A and partner B.
Step 2: A tries to share something important with B, but B does not listen.
Step 3: A reflects on how it felt when B did not listen.
Step 4: In a class discussion create a T-chart to show what a good listener "looks like" and "sounds like."
Step 5: Repeat step 2.
Step 6: A reflects on how it felt when B listened.

Teaching the skills of Encouraging:

Step 1: Give all students a pre-test on vocabulary.
Step 2: Students create flash cards on words he/she missed on the pre-test.
Step 3: Students play the "Flash Card Game" to win back their cards. *(if a tutee answers correctly, the tutor gives an exaggerated praise, such as: "you are a fabulous learner.")*
Step 4: Students take a practice test on all the words he/she has practiced.
Step 5: Students continue to play "Flash Card Game" until they have won back all of their cards.

Appendix K

Sample Test Questions

1. Is x = 7 a solution of the inequality $5 + 2x \leq 15$? Explain why or why not.

2. Define algebraic expression.

3. During a golf game, you score an 83 on an 18-hole course. What was your avegage score per hole? Is this average better or worse than a score of 44 for 9 holes of golf? How do you know? Explain your answer.

4. Explain the step by step process for solving the following linear equation: $4k - 2(3 - k) = -13$.

5. Describe any pattern that you see in the scatterplot.

6. Explain the difference between a positive and negative slope.

7. Define (the meaning of) y-intercept.

8. What does the slope of weekly income represent?

9. Explain how to add or subtract integers.

10. What methold would you use to solve the system of equations? Why?

11. Explain or show why $a^0 = 1$.

12. Explain the differences and similarities between linear equations, quadratic equatio, and absolute value equations.

13. Predict the number of solutions for $x^2 - 5x + 13 = 0$, and explain how you came up with this prediction.

14. Explain why you think your answer is right.

Appendix L

Group Self-Evalutions

Evaluatior Name_____ Group #_____

Use the following scale for all questions:

Never	Rarely	Sometimes	Often	Usually	Consistently
0	1	2	3	4	5

Person 1 **Name**_____

1. This person is willing to help and explain when asked.
   0 1 2 3 4 5

2. This person does their share of group work.
   0 1 2 3 4 5

3. This person gives logical explanations as opposed to saying, "Just because." or "Believe me."
   0 1 2 3 4 5

4. This person contributes to learning and the sense of enjoyment that should come form working in groups.
   0 1 2 3 4 5

Write the sum of the 4 scores for person 1 in the blank. (If person 1 is you, please also circle the sum.) **SUM =** _____

Person 2 **Name**_____

1. This person is willing to help and explain when asked.
   0 1 2 3 4 5

2. This person does their share of group work.
   0 1 2 3 4 5

3. This person gives logical explanations as opposed to saying, "Just because." or "Believe me."
   0 1 2 3 4 5

4. This person contributes to learning and the sense of enjoyment that should come form working in groups.
   0 1 2 3 4 5

Write the sum of the 4 scores for person 1 in the blank. (If person 1 is you, please also circle the sum.) **SUM = _____**

(Appendix L - Continued)

Use the following scale for all questions:

Never	Rarely	Sometimes	Often	Usually	Consistently
0	1	2	3	4	5

Person 3 **Name_____**

1. This person is willing to help and explain when asked.
   0 1 2 3 4 5

2. This person does their share of group work.
   0 1 2 3 4 5

3. This person gives logical explanations as opposed to saying, "Just because." or "Believe me."
   0 1 2 3 4 5

4. This person contributes to learning and the sense of enjoyment that should come form working in groups.
   0 1 2 3 4 5

Write the sum of the 4 scores for person 3 in the blank. (If person 1 is you, please also circle the sum.) **SUM = _____**

Person 4 **Name_____**

1. This person is willing to help and explain when asked.
   0 1 2 3 4 5

2. This person does their share of group work.
   0 1 2 3 4 5

3. This person gives logical explanations as opposed to saying, "Just because." or "Believe me."
   0 1 2 3 4 5

4. This person contributes to learning and the sense of enjoyment that should come form working in groups.
   0 1 2 3 4 5

Write the sum of the 4 scores for person 4 in the blank. (If person 1 is you, please also circle the sum.) **SUM = _____**